

INDOOR AIR QUALITY ASSESSMENT

**Julia Bancroft Elementary School
3 Vinal Street
1956 Wing
Auburn, Massachusetts**



Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Bureau of Environmental Health Assessment
Emergency Response/Indoor Air Quality Program
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Background/Introduction

At the request of Mr. Rocco Morano, School Principal, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA) was asked to provide assistance and consultation regarding indoor air quality at the Julia Bancroft Elementary School (JBES), 3 Vinal Street, Auburn, Massachusetts. On January 8, 2004, Cory Holmes, Environmental Analyst of the Emergency Response/Indoor Air Quality (ER/IAQ) Program, conducted an indoor air quality assessment.

The JBES is a two-story, red brick building with an occupied basement that was constructed in 1917. A one-story addition was built in 1956 and in 2002, two modular classroom units were added. A hallway connects the 1956 wing and modular units to the original 1917 building. Windows in both buildings were reportedly replaced twelve years ago and are now in disrepair, leaving many of them unopenable or difficult to open. The original 1917 building and the 1956 wing contain separate ventilation systems that function independently of one another. Because the buildings have independent ventilation systems, they are the subject of separate reports. This report discusses findings at the JBES 1956 building and modular classrooms.

Methods

Air tests for carbon dioxide, carbon monoxide, temperature and relative humidity with the TSI, Q-TRAK™ IAQ Monitor, Model 8551. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic compounds (TVOCs) was conducted using a Thermo Environmental Instruments Inc., Model 580 Series Photo Ionization Detector (PID).

Results

The 1956 wing and modular unit houses approximately 190 students in grades three through five and a staff of approximately 30. Tests were taken under normal operating conditions and results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were above 800 parts per million parts of air (ppm) in all areas surveyed, indicating inadequate air exchange throughout the school on the day of the assessment. Fresh air in classrooms is supplied by a unit ventilator (univent) system. Univents are designed to draw air from outdoors through a fresh air intake located on the exterior walls of the building (Picture 1) and return air through an air intake located at the base of each unit ([Figure 1](#)). Fresh and return air are mixed and filtered, then heated and provided to classrooms through a fresh air diffuser located in the top of the unit. Univents are reportedly original equipment, approximately 40-50 years old. Univents of this age are difficult to maintain because replacement parts are often unavailable. Most the univents were operating during the assessment. The univent in classroom 5 had been deactivated by the occupant, due to noise. Obstructions to airflow, such as papers and books stored on univents and bookcases, carts and desks in front of univent returns, were seen in a number of classrooms (Pictures 2 and 3). In order for univents to provide fresh air as designed, units must remain activated and allowed to operate while these rooms are occupied. Intakes must also remain free of obstructions.

Ventilation for modular classrooms is provided by AHUs mounted on the exterior of the building (Picture 7). Fresh air is distributed to classrooms via ductwork connected to ceiling-

mounted air diffusers. Return vents draw air back to the units through wall-mounted grilles (Picture 8). Thermostats control each heating, ventilating and air conditioning (HVAC) system and have fan settings of “on” and “automatic”. Thermostats were set to the “automatic” setting (Picture 9) in all of the modular rooms surveyed during the assessment. The automatic setting on the thermostat activates the HVAC system at a preset temperature. Once the preset temperature is reached, the HVAC system is deactivated. Therefore, no mechanical ventilation is provided until the thermostat re-activates the system.

Exhaust ventilation in classrooms is provided by a mechanical system. The exhaust system in each classroom consists of ducted, grated wall vents. Classroom air is drawn out of the indoor environment by rooftop motors (Picture 4). A number of exhaust vents were not operating, or were operating weakly and/or backdrafting, indicating that motors were deactivated or non-functional. In addition, desks, bookcases, shelving and other items (Pictures 5 and 6) blocked a number of the vents in both buildings. As with the univents, in order to function properly, exhaust vents must be activated and remain free of obstructions.

To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a univent and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. The date of the last balancing of these systems was not available at the time of the assessment. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994).

The Massachusetts Building Code requires that each room have a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or openable windows

(SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The MDPH uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools because a majority of occupants is young and considered a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches ([Appendix A](#)).

Temperature readings ranged from 68° F to 73° F, which were close to the BEHA recommended comfort guidelines during the assessment. The BEHA recommends that indoor air temperatures be maintained in a range of 70° F to 78° F in order to provide for the comfort of building occupants. Temperature complaints were expressed in a number of areas. As discussed previously, windows in the building are difficult to operate. A number of classrooms had windows that could not be completely closed creating drafts (Picture 10). In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically

experienced, even in a building with an adequate fresh air supply. In addition, it is difficult to control temperature and maintain comfort without operating the ventilation equipment as designed (e.g., exhaust vents obstructed/deactivated).

The relative humidity ranged from 16 to 28 percent, which was below the BEHA recommended comfort range. The BEHA recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity would be expected to drop below comfort levels during the heating season. The sensation of dryness and irritation is common in a low relative humidity environment. Humidity is more difficult to control during the winter heating season. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

Water-damaged ceiling plaster, which is evidence of water penetration, was observed in the teacher's workroom, which is (Picture 10). Water-damaged building materials can provide a source of mold and should be replaced or repaired after a water leak is discovered and repaired.

In a number of classrooms windows do not close completely, which allows for drafts and moisture penetration (Picture 11). Repeated water damage can result in mold colonization of window frames and porous materials. Once mold has colonized these materials, they are difficult to clean and should be replaced.

Plants were noted in several classrooms. Plants can be a source of pollen and mold, which can be respiratory irritants for some individuals. Plants should be properly maintained and equipped with drip pans. Plants should also be located away from univents to prevent the aerosolization of dirt, pollen or mold (Picture 2).

Other Concerns

Indoor air quality can be adversely impacted by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants; however, the pollutant produced is dependent on the material combusted. Common combustion products include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM_{2.5}) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, BEHA staff obtained measurements for carbon monoxide and PM_{2.5}. Outdoor carbon monoxide concentrations were non-detect or ND (Table 1). Carbon monoxide levels measured in the school were also ND.

Several air quality standards have been established to address carbon monoxide pollution and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions of reduce carbon monoxide levels (MDPH, 1997).

ASHRAE has adopted the National Ambient-Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from 6 criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2000). As recommended by ASHRAE, pollutant levels of fresh air introduced to a

building should not exceed the NAAQS (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS established by the US EPA, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000).

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. *Carbon monoxide should not be present in a typical, indoor environment.* If it is present, indoor carbon monoxide levels should be less than or equal to outdoor levels.

The NAAQS originally established exposure limits for particulate matter with a diameter of 10 μm or less (PM₁₀). According to the NAAQS, PM₁₀ levels should not exceed 150 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$) in a 24-hour average. This standard was adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent, PM_{2.5} standard requires outdoor air particulate levels be maintained below 65 $\mu\text{g}/\text{m}^3$ over a 24-hour average. Although both the ASHRAE standard and BOCA Code adopted the PM₁₀ standard for evaluating air quality, BEHA uses the more protective proposed PM_{2.5} standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM_{2.5} concentrations were measured at 7 $\mu\text{g}/\text{m}^3$ (Table 1). PM_{2.5} levels measured indoors ranged from 3 to 25 $\mu\text{g}/\text{m}^3$, which were well below the NAAQS of 65 $\mu\text{g}/\text{m}^3$. Although PM_{2.5} measurements were above background in some areas, they were below the NAAQS of 65 $\mu\text{g}/\text{m}^3$. Frequently, indoor air levels of particulates (including PM_{2.5}) can be at

higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulate during normal operations. Sources of indoor airborne particulates may include but are not limited to particles generated during the operation of fan belts in the HVAC system, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices; operation of an ordinary vacuum cleaner and heavy foot traffic indoors.

Indoor air quality can also be impacted by the presence of materials containing volatile organic compounds (VOCs). VOCs are substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. Outdoor air samples were taken for comparison. Outdoor TVOC concentrations were non-detect (ND) (Table 1). Indoor TVOC measurements throughout the building were also ND. Please note, that the TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling. Indoor air concentrations can be greatly impacted by the use TVOC containing products (e.g., use of product increases the concentration of TVOC within a classroom). While no measure able TVOC levels were detected in the indoor environment, VOC-containing materials were noted. Cleaning products were found on countertops and beneath sinks in a number of classrooms. Cleaning products contain VOCs and other chemicals, which can be irritating to the eyes, nose and throat and should be stored properly and kept out of reach of students.

The faculty workroom contains photocopiers and lamination machines. Lamination machines can produce irritating odors during use. VOCs and ozone can be produced by photocopiers, particularly if the equipment is older and in frequent use. Ozone is a respiratory irritant (Schmidt Etkin, 1992). The workroom is not equipped with local exhaust ventilation to help reduce excess heat and odors in these areas.

Several other conditions were that can affect indoor air quality noted during the assessment. A number of univents had accumulated dust, cobwebs and debris within the air handling chambers (Pictures 12 and 13). In order to avoid this equipment serving as a source of aerosolized particulates, the air handling sections of the univents and AHUs should be regularly cleaned (e.g. during regular filter changes). A number of exhaust vents in classrooms and restrooms had accumulated dust (Picture 14). If exhaust vents are not functioning, backdrafting can occur, which can re-aerosolize dust particles. In addition, these materials can accumulate on flat surfaces (e.g., desktops, shelving and carpets) in occupied areas and subsequently be re-aerosolized causing further irritation. Dust can be irritating to eyes, nose and respiratory tract.

Also of note was the amount of materials stored inside classrooms. In classrooms throughout the school, items were observed on windowsills, tabletops, counters, bookcases and desks. The large number of items stored in classrooms provides a source for dusts to accumulate. These items, (e.g., papers, folders, boxes) make it difficult for custodial staff to clean. Items should be relocated and/or be cleaned periodically to avoid excessive dust build up.

Several rooms had damaged walls (Picture 15). These breaches can provide a pathway for the movement of drafts, dusts and particulate matter between rooms and floors.

In an effort to reduce noise from sliding chairs, tennis balls were sliced open and placed on chair legs (Picture 16). Tennis balls are made of a number of materials that are a source of

respiratory irritants. Constant wearing of tennis balls can produce fibers and to off-gas TVOCs. Tennis balls are made with a natural rubber latex bladder, which becomes abraded when used as a chair leg pad. Use of tennis balls in this manner may introduce latex dust into the school environment. Some individuals are highly allergic to latex (e.g., spina bifida patients) (SBAA, 2001). It is recommended that the use of materials containing latex be limited in buildings to reduce the likelihood of symptoms in sensitive individuals (NIOSH, 1997). A question and answer sheet concerning latex allergy is attached as [Appendix B](#) (NIOSH, 1998).

Finally, during a perimeter inspection of the building, BEHA staff observed several bees/wasps nests on the exterior of the building. Under current Massachusetts law (effective November 1, 2001) the principles of integrated pest management (IPM) must be used to remove pests in state buildings (Mass Act, 2000). Pesticide use indoors can introduce chemicals into the indoor environment that can be sources of eye, nose and throat irritation.

Conclusions/Recommendations

The conditions related to indoor air quality problems at the JBES raise a number of issues. The general building conditions, maintenance, work hygiene practices and the condition of HVAC equipment, if considered individually, present conditions that could degrade indoor air quality. When combined, these conditions can serve to further degrade indoor air quality. Some of these conditions can be remedied by actions of building occupants. Other remediation efforts will require alteration to the building structure and equipment. For these reasons, a two-phase approach is required for remediation. The first consists of **short-term** measures to improve air quality and the second consists of **long-term** measures that will require planning and resources to adequately address the overall indoor air quality concerns.

The following **short-term** measures should be considered for immediate implementation:

1. Examine each univent for function. Survey classrooms for univent function to ascertain if an adequate air supply exists for each room. Consider consulting a heating, ventilation and air conditioning (HVAC) engineer concerning the calibration of univent fresh air control dampers throughout the JBES.
2. Operate all ventilation systems that are operable throughout the building (e.g., gym, auditorium, classrooms) continuously during periods of school occupancy and independent of thermostat control. To increase airflow in classrooms, set univent controls to “high”.
3. Set the thermostat for modular classrooms to the fan “on” position to operate the ventilation system continuously during the school day.
4. Inspect exhaust motors and belts for proper function. Repair and replace as necessary.
5. Remove all blockages from univents and exhaust vents to ensure adequate airflow.
6. Consider having ventilation systems re-balanced every five years by an HVAC engineering firm.
7. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

8. Ensure roof leaks are repaired and repair/replace any remaining water-stained ceiling tiles and/or plaster. Examine the area above and around these areas for mold growth.
Disinfect areas of water leaks with an appropriate antimicrobial.
9. Move plants away from univents in classrooms. Avoid over-watering and examine drip pans periodically for mold growth. Disinfect with an appropriate antimicrobial where necessary.
10. Make repairs to wall damage in classrooms, to prevent the egress of dirt, dust and particulate matter into classrooms.
11. Change filters for air-handling equipment as per the manufacturer's instructions or more frequently if needed. Vacuum interior of units prior to activation to prevent the aerosolization of dirt, dust and particulates. Ensure filters fit flush in their racks with no spaces in between allowing bypass of unfiltered air into the unit.
12. Clean univent return vents and exhaust vents periodically of accumulated dust.
13. Relocate or consider reducing the amount of materials stored in classrooms to allow for more thorough cleaning. Clean items regularly with a wet cloth or sponge to prevent excessive dust build-up.
14. Store cleaning products properly and out of reach of students.
15. Use the principles of integrated pest management (IPM) to rid the building. A copy of the IPM recommendations can be obtained from the Massachusetts Department of Food and Agriculture (MDFA) website at the following website:

http://www.state.ma.us/dfa/pesticides/publications/IPM_kit_for_bldg_mgrs.pdf.
16. Consider discontinuing the use of tennis balls on chairs to prevent latex dust generation.

17. Consider developing a written notification system for building occupants to report indoor air quality issues/problems. Have these concerns relayed to the maintenance department/building management in a manner to allow for a timely remediation of the problem.
18. Consider adopting the US EPA document, “Tools for Schools”, to maintain a good indoor air quality environment on the building. This document can be downloaded from the Internet at: <http://www.epa.gov/iaq/schools/index.html>.
19. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. These materials are located on the MDPH’s website at <http://www.state.ma.us/dph/beha/iaq/iaqhome.htm>.

The following **long-term measures** should be considered:

1. Replace/repair window systems throughout the building -wide to prevent water penetration and drafts through window frames. Consider having exterior brick re-pointed and waterproofed to prevent water intrusion. Weatherproofing materials should be applied during periods when the school is not occupied.
2. Consider installing local exhaust vents in teacher’s workrooms to help reduce excess heat and odors from office equipment.

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Picture 1



Univent Fresh Air Intake 1956 Wing

Picture 2



Plants and Other Items on and In Front of Classroom Univent

Picture 3



Items Obstructing Univent Airflow in Classroom

Picture 4



Rooftop Exhaust Vents 1956 Wing

Picture 5



Classroom Exhaust Vent Obstructed by Various Items

Picture 6



Items Stored Under Stage Obstructing Airflow Into Vent

Picture 7



AHU for Modular Unit

Picture 8



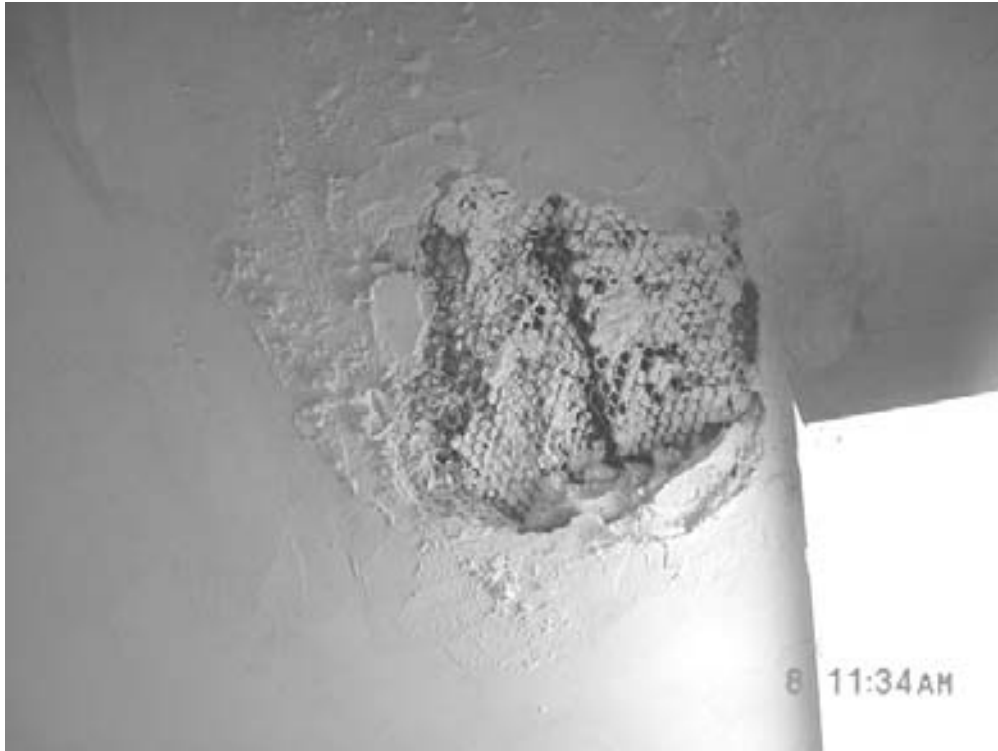
Ceiling Mounted Supply Vent and Wall Mounted Return Vent in Modular Classroom

Picture 9



Modular Classroom Thermostat Note Fan Setting to “Auto”

Picture 10



Water Damaged Ceiling Plaster in Teacher's Workroom

Picture 11



Classroom Window That Does Not Close Properly Sealed With Tape to Reduce Drafts

Picture 12



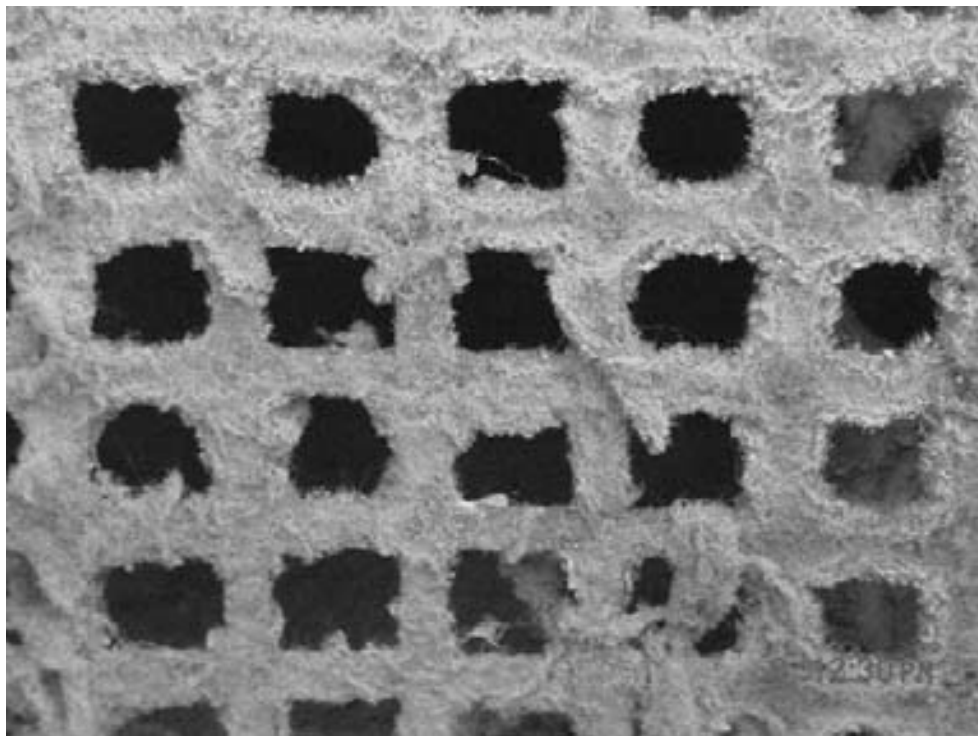
Cobwebs and Dust Accumulation in Classroom Univent

Picture 13



Univent Filter Occluded With Dust and Debris

Picture 14



Classroom Exhaust Vent With Accumulated Dust

Picture 15



Damaged Wall in Classroom

Picture 16



Tennis Balls on Chair Legs in Classroom

Bancroft Elementary School 1956 Wing and Modular Units
Vinal Street, Auburn, MA

Table 1

Indoor Air Results
January 8, 2004

Location/ Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (µg/m3)	Occupants in Room	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
Background (outdoors)	32	22	336	ND	ND	7		-	-	-	Cold, clear skies, sunshine, NW winds 15-20 mph
Main Office	70	26	1203	ND	ND	9	2	N	N	N	Lamination machine
Teacher's Work Room	71	28	1057	ND	ND	7	1	N	N	N	Water damaged CP-roof leaks, photo copiers
Gym Cafeteria	73	23	1001	ND	ND	4	23	N	Y	Y	Exhaust vent under stage used for storage
1	74	24	1234	ND	ND	15	24	Y	Y	Y	Exhaust vent off-backdrafting, AC-dusty, dust acuum on flat surfaces/windowsills, water fountain leak, TB
2	71	19	1503	ND	ND	25		Y	Y	Y	Accumulated items in classroom, DEM, dust, aquarium, nests, plants, cleaning products, UV blocked

ppm = parts per million parts of air
µg/m3 = microgram per cubic meter

AD = air deodorizer
AP = air purifier

CD = chalk dust
DEM = dry erase marker
DO = door open
ND = non detect
PC = photocopier

PF = personal fan
TB = tennis balls
UF = upholstered furniture
UV = univent

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred 600 - 800 ppm = acceptable > 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

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									Supply	Exhaust	
Classroom 3	73	23	1462	ND	ND	9	23	Y	Y	Y	Accumulated items in classroom, DEM, dust, cleaning products, UV blocked, exhaust vent off-blocked
Classroom 8	73	21	1374	ND	ND	10	21	Y	Y	Y	UV-weak, exhaust vent off-blocked, DEM, cleaning products
Classroom 4	73	17	1205	ND	ND	9	17	Y	Y	Y	Exhaust vent off-backdrafting
Classroom 7	72	17	1190	ND	ND	6	25	Y	Y	Y	Exhaust weak, wall damage, DEM, cleaning products, dust
Classroom 6	73	16	990	ND	ND	6	24	Y	Y	Y	Exhaust vent off-blocked, TB, wall damage, DEM, dust, cleaning products
Classroom 5	68	19	1670	ND	ND	13	21	Y	Y	Y	UV deactivated by occupant due to noise, DEM, cleaning products, dust
Modular Resource	72	19	1019	ND	ND	6	3	Y	Y	Y	Thermostat Fan – Auto, DEM

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									Supply	Exhaust	
Room											
Modular Conference Room	73	20	845	ND	ND	3	5	Y	Y	Y	Thermostat Fan – Auto, DEM

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